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Characterizing Seagrass Exposure to Light Attenuation and Turbidity Associated with Dredging Activity in the Gulf Intracoastal Waterway, Sarasota Bay, Florida

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PURPOSE: This technical note describes the collection of light attenuation and turbidity data associated with a dredging event conducted by the U.S. Army Corps of Engineers (USACE) special purpose dredge the *Murden*. Light attenuation is a measurement of the loss of light that photosynthetic aquatic resources depend on for survival while turbidity is water clarity standard used in the regulatory system as a quick and easy technique to assess water quality degradation. There are several ways dredging activities can impact environmental resources: direct physical disturbance, increased light attenuation through the water column, abrasion of the leaves, sediment settling on blades, and burial due to sedimentation. Potential dredging effects on seagrasses can be classified into two types: direct and indirect. Direct impacts are defined as the physical removal of existing submerged aquatic vegetation within the dredging footprint. Indirect impacts to seagrasses may occur in areas near the dredged areas but not physically disturbed by the dredging equipment, due to temporary increases in water column light attenuation or sedimentation. Indirect impacts are more challenging to detect against a background of natural spatial and temporal variability. This technical note includes details of the field data collection and comparisons among the various types of data.

BACKGROUND: This monitoring effort was a project of opportunity occurring in an environmentally significant area, Sarasota Bay in Southwest Florida. Large, mixed-species seagrass meadows occur within and immediately adjacent to the channel dredging boundary. Direct impacts to seagrass existing within the boundaries of the Federal channel are expected to occur as a result of the dredging maintenance activity, as well as some temporal loss within the buffer immediately adjacent to the channel that occurs as a result of side-slope slumping during dredging. Seagrasses immediately adjacent to the dredged channel have the potential to be indirectly affected by temporary increases in water column light attenuation or sedimentation associated with the dredging activity. Since indirect dredging impacts are much more difficult to quantify, this effort was aimed at qualitatively and quantitatively evaluating seagrass exposure to resuspended material resulting from dredging activities. This study presents the results of a monitoring effort designed to examine the light attenuation and turbidity characteristics of the dredged material plume in relationship to background data in order to assess the potential for indirect impacts to seagrasses due to exposure to dredged material plumes.

Sarasota Bay, a 56-mile long coastal lagoon located in southwest Florida, stretches from Anna Maria Sound at the northern end to Venice Inlet at the south end. It was identified as an Estuary of National Significance in 1987 by the U.S. Congress (SBEP 2006) and was formally designated as a National Estuary Program estuary in 1989. The subtropical climate is greatly influenced by the proximity of the Gulf of Mexico. Annual precipitation averages some 60 in. per year on Longboat Key and Anna Maria Island, with a recorded extreme maximum temperature of 96 ˚Fahrenheit (F), an extreme minimum temperature of 38 ˚F, and an average temperature of 81 ˚F (SBEP 2006). Sarasota Bay supports a wide variety of aquatic life, including species of fin fish, invertebrates, and shrimp. Florida Department of Environmental Protection classifies the waters of Sarasota Bay and Tampa Bay as Outstanding Florida Waters. Portions of Gulf Intracoastal Waterway (GIWW) that include Cuts M-5, M-12, and M-14, as well as Longboat Pass Cut 3 (Figure 1), are located within the Sarasota Bay Aquatic Preserve.

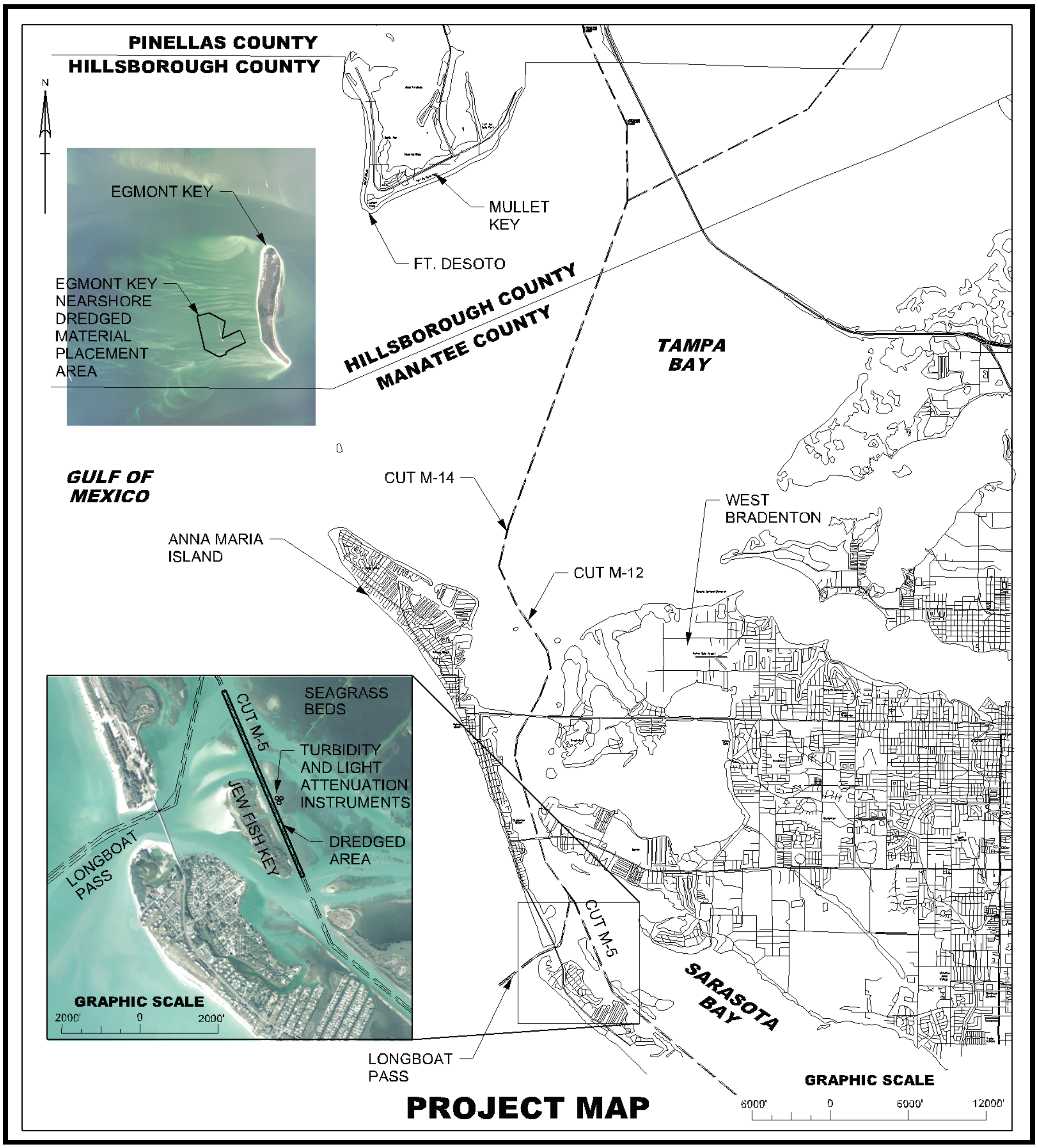

Figure 1. Map of study area indicating locations of dredging activity.

Federal authorization of the GIWW was allocated as early as 1890, when a shipping channel was funded and constructed within Sarasota Bay reaching to Tampa Bay. The original dimensions of the GIWW within this area were authorized at 100 ft in width and 9 ft in depth. The 148-mile segment of the GIWW, from the Caloosahatchee River to the Anclote River, was constructed between 1960 and 1967 (Alperin 1983). The channel between these two rivers was routed east of the barrier islands or *keys* to protect the channel and vessels from storm effect. Subsequent maintenance dredging for the GIWW within the project area is believed to have occurred since the 1960s, but this is unverified.

DESCRIPTION OF DREDGING OPERATIONS: The Federal navigation project described in this technical note is located along the GIWW within Sarasota Bay adjacent to Longboat Key, Jewfish Key, and Anna Maria Island, Gulf of Mexico, Manatee County, Section 9, 10, 15, 16, Township 35 South, Range 16 East, Florida. During the development of this project, the entire GIWW and adjoining Longboat Pass were evaluated to identify the channel cuts most in need of maintenance dredging. The scoping process originally identified Cuts M-5, a section of M-12, and a section of M-14 as the most critical cuts requiring maintenance for safe navigation. Cut M-5 required the most extensive dredging, a total of 45,000 yd^3 over a length of approximately one mile (Table 1). Longboat Pass Cut 3 also exhibited extensive accumulation of shoal material.

Table 1. Description of maintenance dredging areas.

Cut Name	Station/Length	Linear Feet	Dredged Volume (yd^3)	Authorized Depth + AO1
GIWW M-5	2+00 – 19+00; 21+00 – 57+00	5,300	45,000	-9.0 + 2
GIWW M-12	23+00 – 37+00	1,400	7,000	-9.0 + 2
GIWW M-14	0+00 – 7+00	700	12,500	-9.0 + 2
LB Cut 2	17+00 – 20+50	350	3,000	-10.0 + 2
LB Cut 3	0+00 – 19+00	1,900	27,000	-10.0 + 2

AO1 = Allowable Overdepth

Dredging for this project was conducted by the Corps dredge *Murden*. Since this was a government dredge, the team was assured good communication with the dredge personnel and were able to track the operations more closely than when private dredge plants are used. The dredging process during this project consisted of 6-days-a-week operations; crew changes and fueling days occurred on Wednesdays. The standard work day commenced at 6:00 a.m. and continued for 12 hours. After the startup procedures were complete and initial checks performed, transit to the dredging site commenced. Typically, during loading operations, the dredge would transit back and forth over a 5,000 ft section of channel approximately six times. Approximately 1 to 1.5 hours of dredging were necessary to obtain a nearly full load. After approximately 5 minutes of dredging, the hopper would fill to the weirs with water, thus overflow was occurring nearly the entire time during dredging operations and for approximately one-half hour afterwards. Once the hopper was full, transit time to the disposal site at Egmont key took approximately 2.5 hours. Two loads were completed each day.

Multiple small research vessels were used to measure and track the dredging and placement plumes using pump samplers, acoustic Doppler current profilers, and turbidity probes. As part of this overall experiment, inflow slurry and overflow water samples were collected along with cores of the dredged material within the dredge's hopper. This data is presented in the associated publication *Dredge Monitoring and Plume Tracking Mass Balance Approach, GIWW Bradenton and Egmont Key, Florida*, while this technical note focuses only on turbidity and light attenuation in the vicinity of seagrass beds.

DREDGING EFFECT ON SEAGRASSES: Three species of seagrass, turtle grass (*Thalassia testudinum),* shoal grass (*Halodule wrightii)*, and manatee grass (*Syringodium filiforme),* are found throughout the GIWW and Longboat Pass cuts. A seagrass survey conducted in 2010 included the 100 ft Federal channel and two 100 ft buffers on either side of the channel. Although a minor amount of seagrass occurred within the GIWW channel, the densest populations were found concentrated in the shallow areas immediately adjacent to the channel edges. The highest seagrass density was present within and immediately adjacent to Cut M-5 by Jewfish Key and one colony within Cut M-14 (Figure 1**)**. A total of 0.33 acre of seagrass occurs within the proposed dredge area of GIWW Cuts M-5 and M-14. Cut M-12 did not contain any seagrass within the proposed dredging area; however, colonies were located immediately adjacent to the channel.

METHODS: Due to the close proximity of seagrass resources to the edge of the navigation channel, this was an ideal field site for monitoring seagrass exposure to dredge plume migration and dissipation. To address water quality degradation concerns, the State of Florida Department of Environmental Protection requires in-water construction projects to meet certain turbidity criteria. The standard protocol employed to maintain compliance assurance with the state standards is to conduct turbidity measurements twice a day outside of an allowed mixing zone in the visually densest portion of the plume. Since suspended material created by dredging activities reflect and absorb sunlight reducing the depth at which photosynthesis can occur, it was decided to collect both the state standard turbidity values and light attenuation data for comparison.

Turbidity Measurements. Turbidity monitoring has been shown to be an effective tool to prevent or minimize environmental impacts to seagrasses associated with dredging operations (Erftemeijer and Lewis 2006). During the stationary experiments on 15 and 17 March, turbidity and water level fluctuations were measured along with the light attenuation measurements. In addition, underwater video cameras were used to provide a visual record of the dredging plume; still photos were taken every 10 sec by a second camera. A YSI 600 series Optical Monitoring System (OMS) was deployed simultaneously with light meters. The OMS sensor was located at approximately the same level (22 in. from the bottom) as the bottom light sensor, sampling at 0.5 Hz.

Light Attenuation Measurements. Two spherical underwater quantum light sensors (LI 193SA, LICOR, Inc.) were used to record simultaneous light data in the vicinity of the dredging operations. These sensors are accurate to within $\pm$5%, and the data are recorded with a precision of ± 0.01 µm m^{-2} s^{-1} (LICOR, Inc.). The recorded light integration period was set at 1 min. Two sensors were deployed at each location to allow calculation of diffuse attenuation coefficients. The bottom sensor was positioned slightly above the seagrass canopy (approximately 22 in. above the bottom); a second sensor was placed 20 in. above the bottom sensor. Diffuse light attenuation coefficients (K_d) were calculated according to the following equation: ($\log_{10} I_t - \log_{10}$

I_b / z (Carruthers et al. 2001), where I_t and I_b = irradiance recorded at the upper and lower sensors, respectively, and z = distance between upper and lower sensors.

Four light datasets were collected over a 3-day period from 15 March 2013 to 17 March 2013. On 15 March 2013, sensors were placed on a stationary tripod near the edge of the channel, and baseline light data were recorded in the absence of dredging activity. On 16 March 2013, the sensors were deployed on a stationary tripod near the edge of the channel to record the plume decay rate following the departure of the dredge. On 17 March 2013, sensors were deployed near the edge of the channel to capture the sediment plume as the dredge made multiple passes.

Pump Sampling – Sediment Solids Concentration. The calibration of OMS sensor data was conducted using the field pump sampling data. A small intake hose for a pump was deployed from a survey boat near and at the same depth as the light attenuation and turbidity instrumentation to collect physical water samples for laboratory analysis using filtration to determine suspended sediment concentrations. Every few minutes, a sample bottle was filled from the pump flow, and the sample time was logged with the offset of the time it took for water to pass through the pump system. This allowed the deployed instruments and pump samples to be referenced based on their time stamp. The nephelometric turbidity unit (NTU) output of the OMS sensor was compared with the concentration in milligram per liter (mg/L) (1 oz per gallon equals 7,490 mg/L) obtained from pump sampling.

RESULTS

Turbidity Measurements. Minor turbidity variances occurred during the 15 March 2013 experiment, due to the lack of dredging activities. This dataset from 15 March documents background conditions for comparison with water column conditions during the dredging activities on 16 and 17 March. The 17 March 2013 dataset captured the onset and subsidence of the dredging related plume. Figure 2A shows an underwater photo at the experiment site before the arrival of the dredging plume. The dense seagrass bed, the scaled rod approximately 12 in. from the camera, and the bottom light meter are visible in Figure 2A. At the peak of the plume at 13:40, neither the light meter nor the scaled rod was visible in Figure 2B. At 14:25, the light meter and the scaled rod had become visible again, similar to the case before the plume arrived, Figure 2C, indicating the rapid dissipation of the turbidity within 1 hour. Based on field observations during the dredging operation, the plume was mainly generated by overflow and dredge movements that occurred during the entire period of dredging.

Temporal Patterns in Light Attenuation. Baseline light attenuation coefficients collected on the afternoon of 15 March 2013 were variable and low, ranging from 0.06 to 0.30, with a mean daily value of 0.17 (Figure 3 and Table 2).

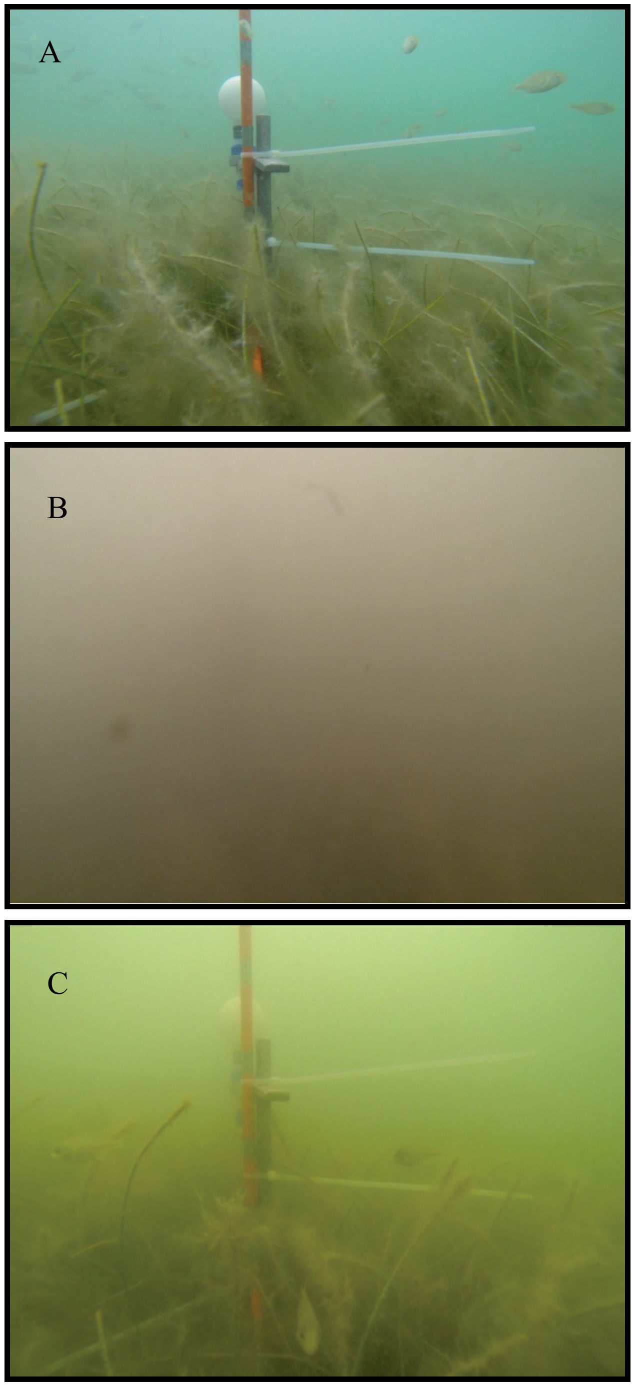

Figure 2. A. Light sensor positioned just above seagrass canopy illustrates baseline clear water conditions prior to the arrival of the dredging plume (12:30 on 17 March 2013). B. Poor visibility during the peak of the dredged material plume (13:40 on 17 March 2013). C. Photo illustrating the rapid dissipation of the plume within one hour after the peak of the plume (14:25 on 17 March 2013). All photos taken from the same camera position.

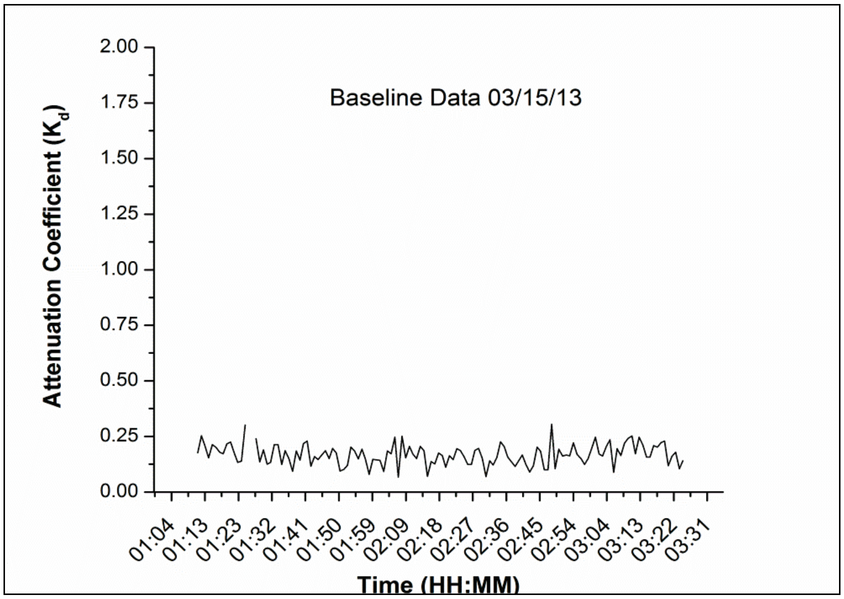

Figure 3. Baseline light attenuation data in the absence of dredging activity on 15 March 2013.

Table 2. Comparison of K_d values for baseline, plume decay, and plume conditions.

Date	Type	Start	Finish	Min	Max	Mean
3/15/2013	Baseline	13:12	15:25	0.067	0.304	0.168
3/16/2013	Plume Decay	13:51	14:41	0.255	0.889	0.462
3/17/2013	Plume	11:16	15:14	0.066	1.82	0.353

Light attenuation data collected on the afternoon of 16 March 2013 illustrate an exponential plume decay rate (Figure 4). The plume migrated the opposite direction from what was anticipated, so the equipment was repositioned, and only the decay of the plume was captured. Dredging operations ceased at approximately 13:35.

After dredging in the immediate vicinity of the sensor array, peak recorded light attenuation coefficient values declined rapidly from approximately 0.9 to near normal background levels within 1 hour (Figure 4). The peak dredging plume signature on 17 March 2013 was characterized by K_d values ranging between 0.5 and 1.8 (Figure 5 and Table 2). K_d values in the seagrass beds immediately adjacent to the channel exceeded a value of 1.0 for a period of approximately 1 hour.

Comparison of Light Attenuation and Turbidity Values. The values for light attenuation (Kd) compare closely to the measured turbidity (Figure 6). However, a significant proportion of the NTU values were negative. It is not clear why the OMS output was negative for much of the data (i.e., below the laboratory zero reading). Prior to deployment, a two-point calibration (0 NTU and 126 NTU) was performed on the 600 OMS turbidity sensor. However, the fluctuation of the positive NTU readings of the OMS sensor within the plume matched well the variation of the light attenuation data. This indicates that the light attenuation is strongly controlled by the turbidity variation, as expected. It also suggests that under these conditions, the light sensors are much more sensitive to small changes in water column clarity than the OMS sensors.

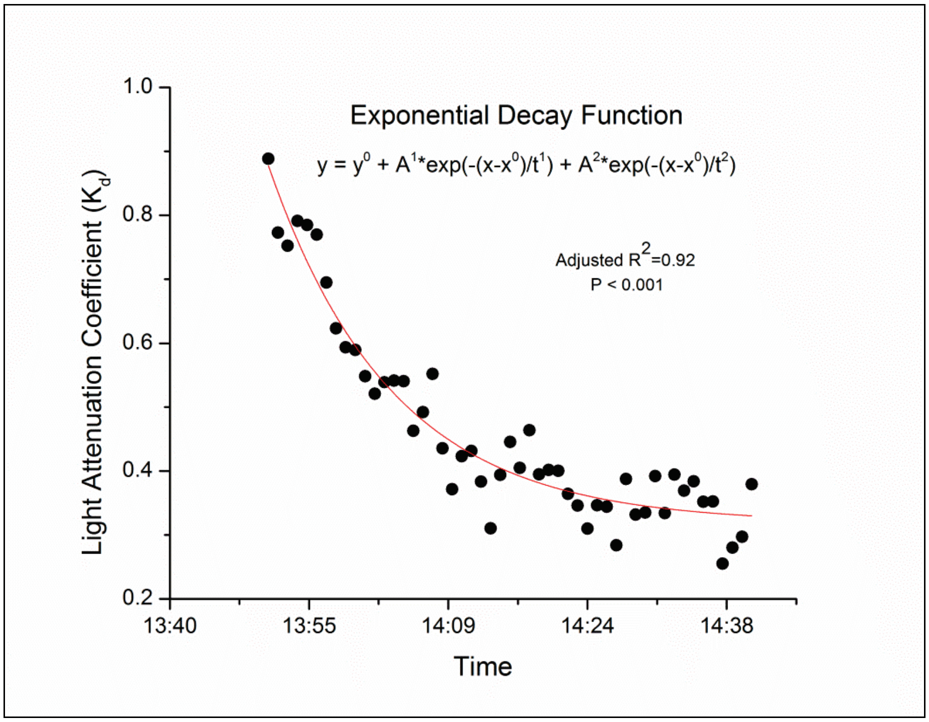

Figure 4. Dredge plume on 16 March 2013 exhibited an exponential rate of decay with a rapid return to near normal baseline conditions within 1 hour.

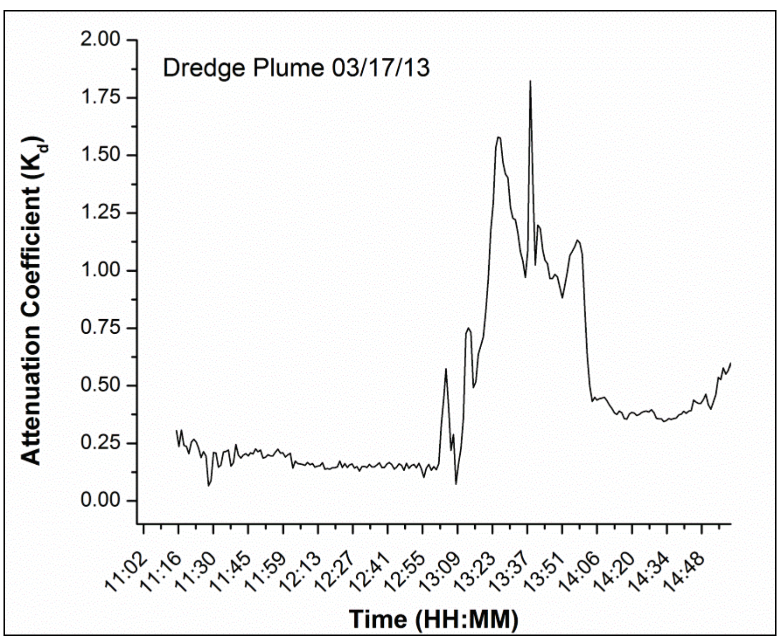

Figure 5. Light attenuation resulting from resuspended dredged material plume associated with multiple passes of the dredge on 17 March 2013.

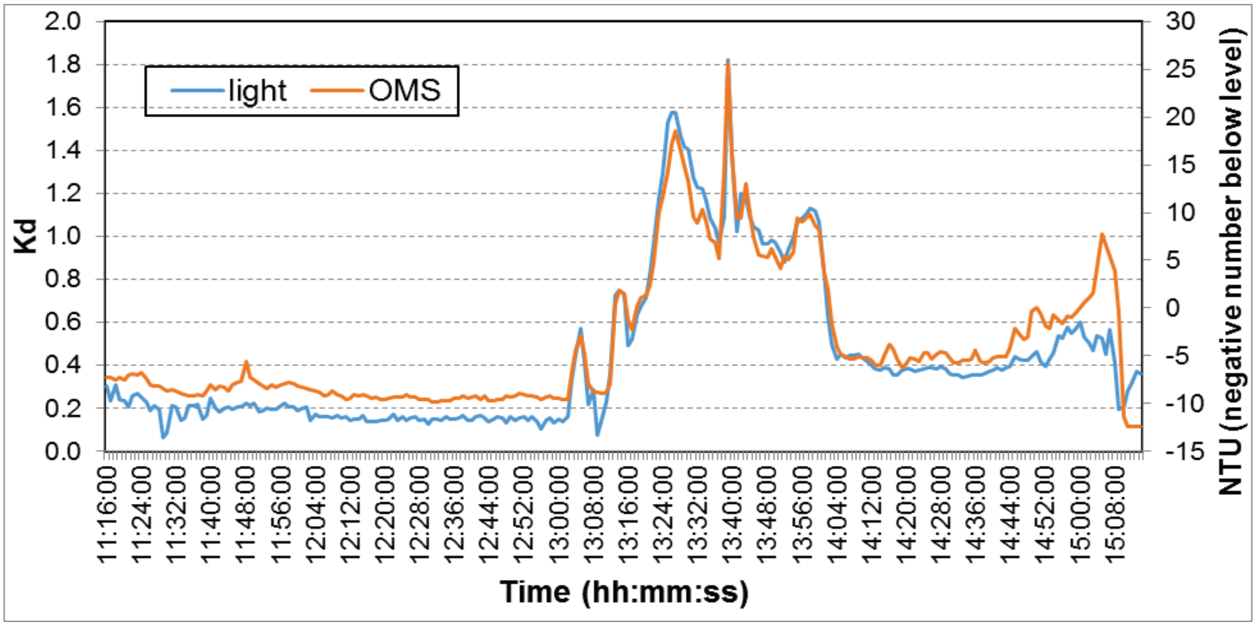

Figure 6. Comparison of measured light attenuation (K_d) and turbidity (NTU) on 17 March 2013.

Relationship between Turbidity and Suspended Solids Concentration. The calibration of OMS sensor data was conducted using the field pump sampling data. The NTU output of the OMS sensor was compared with the concentration in mg/L obtained from pump sampling (Figure 7). Uncertainties associated with pump sampling physical collection, tube length, and mixing may all contribute to the scattering. Based on the calibration data, the suspended sediment concentration during the peak of the dredging plume on 17 March 2013 ranged between 100 and 200 mg/L.

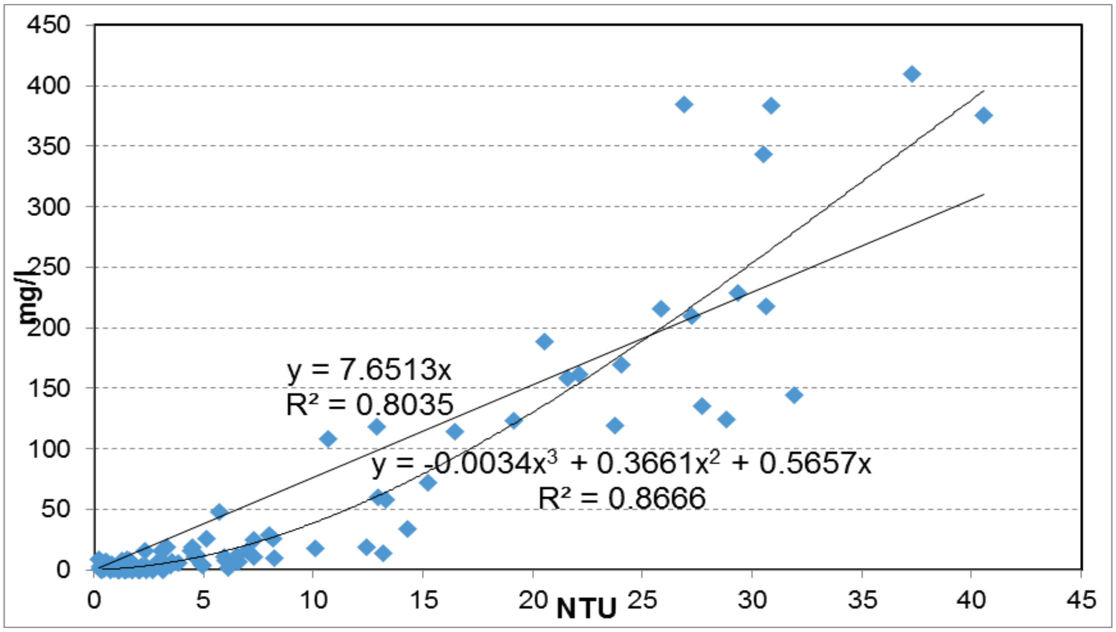

Figure 7. Calibration data for the OMS sensor, NTU readings versus the measured suspended sediment concentrations from pump sampling.

DISCUSSION: The extent of the impacts caused by dredging and disposal operations depends on a number of factors: the quantity, frequency, and duration of dredging, the dredging and disposal methods, water depth, sediment grain size distribution, degree of contamination, background water quality (especially suspended solids and turbidity), seasonal variability in weather conditions (particularly wind and waves), and proximity of the seagrasses or other sensitive resources to the dredging and disposal operations (Pennekamp et al. 1996). The ability to predict seagrass responses to these stressors depends on accurate estimates of seagrass exposure combined with knowledge of threshold physiological responses to light attenuation and resuspended sediments. In this report, there is an evaluation of seagrass exposure using the accepted state water quality turbidity standard (NTU), as well as a more physiologically relevant measure appropriate for interpretation of seagrass responses, light, measured as photosynthetically active radiation.

Seagrass Exposure to Light Attenuation. In some cases, increases in water column attenuation have been associated with declines in seagrass cover and density. For example, an increase in the average annual attenuation coefficient from 0.7 to 1.2, in conjunction with the onset of a brown tide, resulted in a 50% decline in the biomass of *Halodule wrightii* over a 3-year period in Laguna Madre, TX (Dunton 1994). In San Antonio Bay, TX, complete loss of *Halodule wrightii* at a depth of 0.6 m was observed at a site where the average attenuation coefficient was 2.9, although it remained abundant at shallower depths (Dunton 1994). However, seagrasses are naturally adapted to seasonal and stochastic fluctuations in light availability associated with storms, river discharges, etc. Increased turbidity and associated reductions in available light related to dredging operations will result in adverse effects to seagrasses only when the dredging-related turbidity exceeds the range of natural turbidity and sedimentation rates for the area (Erftemeijer and Lewis 2006).

The range of baseline Kd values recorded during this study were generally lower than mean annual values reported for other seagrass beds in Florida (Dixon 2000; Dennison et al. 1993). A mean annual attenuation coefficient of 0.93 was reported for *Halodule wrightii* beds in Florida by Dennison et al. (1993). Mean annual values ranging from 0.80 to 0.94 were reported for four sites in Tampa Bay by Dixon (2000). Dixon (2000) also noted seasonal differences in mean monthly Kd values, with lower values ranging from 0.5 to 0.7 during the winter and early spring (2000). Declines in water clarity in June were associated with increased water column chlorophyll content whereas decreased water clarity in September and October was attributed to increased freshwater input during the rainy season (Dixon 2000). The values recorded in this study were also lower than those recorded during the summer in St. Andrew Bay by Shafer (2003). From 11–26 June 2003, the average daily value for Kd in West Bay, FL, was 0.94, with a range of 0.62 to 1.67. These observations are consistent with the seasonal patterns of Kd reported by Dixon (2000).

The range of light attenuation coefficient values observed during the peak dredging plume (<1.8) was similar to the range of values recorded under normal summer conditions for a healthy seagrass bed in West Bay, FL (Shafer 2003). Furthermore, the duration of light attenuation coefficient values that exceeded a value of 1.0 was very short (approximately 1 hour). Mean annual values ranging from 0.80 to 0.94 were reported for four seagrass sites in Tampa Bay (Dixon 2000). This evidence indicates that the intensity and duration of the light attenuation associated with the dredging operations on 17 March 2013 were well within the normal range of values expected for seagrass beds in the absence of dredging activity. Although some loss of seagrass may occur through direct removal along with the dredged sediments or side slumping within the channel footprint, no indirect (secondary impacts) changes in seagrass distribution, abundance, or density in the area adjacent to the dredged channel would be expected to occur as a result of water column light attenuation.

Comparison of Light Attenuation and Turbidity Values. The clarity of a water body is commonly viewed as a primary indication of water quality. Since in-water construction activities typically create turbulence that can resuspend bottom sediments, it is generally accepted that these projects degrade the surrounding water quality. To address water quality degradation concerns, the State of Florida Department of Environmental Protection requires in-water construction projects to meet certain turbidity criteria. The standard protocol employed to maintain compliance assurance with the state standards is to conduct turbidity measurements twice a day outside of an allowed mixing zone in the visually densest portion of the plume. The light attenuation values showed a very similar pattern as the output of the OMS sensors. It does appear however that the light sensors are much more sensitive to small changes in water column clarity than the OMS sensors. For most standard applications, it appears that OMS sensors can be calibrated to and used to supplement light attenuation data.

SUMMARY: The turbidity maximum levels measured during this project did not exceed natural background variations. The duration of the elevated turbidity plumes were very short lived as anticipated in dynamic areas that experience significant tidal currents. The comparison between light attenuation and turbidity values indicates that these two protocols can be calibrated to one another and that the light attenuation sensors are far more sensitive in measuring minor variations in water clarity.

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> Shafer, D., C. Maglio, K. McConnell, T. Beck, and C. Pollock. 2016. *Characterizing seagrass exposure to light attenuation and turbidity associated with dredging activity in the Gulf Intracoastal Waterway, Sarasota Bay, Florida*. ERDC TN-DOER-E39. Vicksburg, MS: U.S. Army Engineer Research and Development Center. *http://chl.erdc.usace.army.mil/chetn*

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